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DIFFERENCES AMONG BREED CROSSES OF CATTLE IN THE CONVERSION OF FOOD ENERGY TO CALF WEIGHT DURING THE PREWEANING INTERVAL

T. G. Jenkins[1], L. V. Cundiff[1] and C. L. Ferrell[1]

U.S. Department of Agriculture, Agricultural Research Service,
Clay Center, NE 68933-0166

ABSTRACT

The objective of this study was to determine whether F_1 cows that differ in genetic potential for weight at maturity and milk yield vary in the conversion of food energy to calf weight gain. Food intakes and weight change data were recorded by pen for cows and calves from approximately 45 d postpartum. Cows assigned to the study were 7- to 9-yr-old F_1s produced by top-crossing Angus, Hereford, Brown Swiss, Chianina, Gelbvieh, Maine Anjou, and Red Poll sires to either Angus or Hereford dams. Calves were sired by Simmentals. Experimental units were pens (10 to 12 cow/calf pairs); pen was replicated within breed of sire in each of 2 yr (n = 24). Calf weight gain and energy consumed by the dams differed among the F_1s, as did the ratio of calf weight gain to energy consumed by the calf and cow. Angus or Hereford (35.8), Red Poll (35.7), or Maine Anjou (35.6) F_1s produced more calf weight per unit of energy consumed (g/Mcal) by the cow and calf than Chianina (33.1) or Gelbvieh (33.7) F_1 females; Brown Swiss cows were intermediate (34.3). Differences in food conversion efficiency exist among breed crosses. These differences seem to be associated with breed cross differences in genetic potential for milk yield and mature weight; an exception to this trend was the Maine Anjou.
Key Words: Cows, Milk Production, Mature Weight, Efficiency

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Introduction

A marketing endpoint for beef production enterprises occurs relatively soon after progeny are weaned from the cow. Heavier weaning weights of progeny are favored because of their direct effect on output of the production system and their favorable, but low, association with output/input ratios (e.g., Davis et al., 1983a,b). Included among the factors known to affect weight of progeny at weaning are nutritional environment, age at weaning, genetic potential of cattle, and interactions among these factors. Approaches to increase the genetic potential for weaning weight include selection within breed for heavier weights or implementation of mating systems that capitalize on breed differences such as growth or milk production (Gregory and Cundiff, 1980; Long, 1980). These approaches provide opportunities to effectively exploit underlying additive and nonadditive genetic variation to improve the output of an enterprise. Use of breeds or breed crosses of greater genetic potential for performance to improve output can increase the nutrient requirements (input) of the producing females. Variation in progeny weights at weaning, in conjunction with variable nutrient requirements among breeds or breed crosses, suggests that differences exist in conversion of food energy to weight gain of progeny during the preweaning interval.

Objectives of the study were to estimate differences in energy requirements for mainte-

[1]USDA, ARS, Roman L. Hruska U.S. Meat Anim. Res. Center, P.O. Box 166.
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nance and lactation combined and to determine whether differences in the conversion of food energy to calf weight gain during the preweaning period exist among mature F_1 cows representing diverse breeds of cattle.

Materials and Methods

Mature F_1 cows produced in Cycle II of the Germ Plasm Evaluation project (Gregory et al., 1978; Laster et al., 1979; Cundiff et al., 1986) were used in the study. Cows used in the study were produced by top-crossing, through AI, Angus, Hereford, Brown Swiss, Chianina, Gelbvieh, Maine Anjou, or Red Poll sires to Angus or Hereford dams. Angus- and Hereford-sired F_1 cows were considered as a single breed cross. The F_1 cows were 7 to 9 yr of age at the time of the study. Birth date was similar ($\bar{x}$ = 82 d, SD = .9) among cows identified for use in the study. All F_1 cows reared Simmental-sired calves. Male calves were castrated at birth. Calves were born in March or April of each of 2 yr. At a mean age of 35 d (SD = .9), the cow-calf pairs were transferred from pasture to the feedlot. Within breed of sire, 10 to 12 cow-calf pairs were assigned to each of two pens each year. Breed of dam (Angus or Hereford) was balanced within each pen. Initial weights and backfat depth were recorded. A needle probe at approximately 6 cm distal to the 12th thoracic vertebrae provided an indicator of body condition among cows. Average age of the calves at the start of the study was 45 d (SD = .9). Weights of the cows were recorded every 2 wk after the start of the trial. Cows in each pen received a diet of corn silage, alfalfa hay, and supplement (soybean meal, dicalcium phosphate, trace minerals, and vitamin A). The quantity of diet each pen of cows received was adjusted at 2-wk intervals based on the mean weight gain or weight loss of cows, in an attempt to maintain the initial mean cow weight. Two-week feed consumption was recorded for pens. Creep feed was available to the calves ad libitum in pellet form (alfalfa hay, corn, soybean meal, salt, trace minerals, vitamins A, D, E, and binder); the quantity consumed by each pen of calves was recorded. The ME content of the diets was calculated from tabular values. Milk yields at an average of 69, 121, and 201 d postpartum were measured using weigh-suckle-weigh procedures (Notter et al., 1978). Before each sampling time, cow-calf pairs were separated for approximately 12 h. A final fat probe was recorded at the end of the trial. The trial lasted 20 wk and was replicated the following year with each breed cross resampled.

By design, the amount of the diet received by each pen was adjusted every 2 wk in an attempt to maintain weight equilibrium for the cows. Initial estimates of ME required to sustain weight equilibrium were based on estimates obtained on breed crosses with similar production potential (Ferrell and Jenkins, 1984). This experimental protocol was not fully successful (Table 1). The mean 2-wk ME consumption for each pen of cows was adjusted statistically to zero 2-wk weight change using regression procedures. Beginning and ending 2-wk weights of individual cows were averaged within pens. A pen ADG during the 2-wk period was calculated. For each pen, 2-wk ME consumptions were regressed on the pen ADG. The coefficients from these regressions were used to adjust observed pen ME consumption to pen ME required for zero pen weight change during the study. The adjusted ME consumptions were used in the analyses. Creep feed consumption observed was recorded as food ME consumption of the progeny.

Variation in response variables (pen means) was partitioned by two-way ANOVA procedures. Sire breed of dam (5 df), year (1 df), and the two-way interaction (5 df) were considered as sources of variation. When appropriate, contrasts among means for breed of sire of dam were made using a lsd method (Student's *t*-test with a pooled error variance, Steele and Torrie, 1980). The number of comparisons made exceeded the available df. The contrasts were made only when an effect was present, reducing the possibility of incorrectly identifying treatment differences (40%) that may occur when nonindependent comparisons are made.

Results

Results of the ANOVA indicated that the two-factor interaction between year and breed of sire of dam cross was not a significant source of variation for most of the traits of interest. Year of the study was a significant source of variation. The objective was to evaluate sire breed of dam effect among the breed crosses; as such, means associated with

TABLE 1. MEANS AND STANDARD ERRORS FOR PERFORMANCE CHARACTERISTICS OF CROSSBRED COWS

	Sire breed of cow[ab]							
Trait	Angus/ Hereford	Brown Swiss	Chianina	Gelbvieh	Maine Anjou	Red Poll	SEM	Significance
Weight, kg								
Initial	504^{cd}	499^{c}	554^{e}	519^{d}	554^{e}	468^{f}	5.6	**
Final	525^{c}	510^{c}	562^{d}	528^{c}	569^{d}	479^{e}	6.0	**
Backfat, cm[g]								
Initial	$.40^{e}$	$.32^{d}$	$.34^{cf}$	$.33^{df}$	$.32^{d}$	$.36^{c}$	.01	**
Final	$.46^{e}$	$.31^{d}$	$.36^{c}$	$.31^{d}$	$.30^{d}$	$.34^{c}$	.01	**
Milk yield, kg/12 h[h]	3.4^{e}	4.8^{d}	3.3^{e}	4.5^{cd}	4.2^{c}	4.1^{c}	.30	**
Daily metabolizable energy intake, Mcal/d[i]								
Actual	26.9^{e}	29.1^{d}	29.3^{d}	28.9^{d}	28.4^{e}	26.5^{c}	.37	**
Adjusted	24.9^{e}	28.6^{d}	28.3^{d}	28.6^{d}	27.4^{e}	26.2^{c}	.46	**

[a]Mated to Hereford and Angus cows.

[b]Four pens/sire breed of cow group.

[c,d,e,f]Means within row with different superscripts differ ($P < .05$).

[g]Probe at last rib; includes depth of hair coat and hide.

[h]Mean of three measurements taken at 69, 121, and 201 d postpartum.

[i]Adjusted daily ME intake reflects predicted daily ME energy intake for zero weight change.

$^{**}P < .01$.

the effect of year were not reported for the traits of interest.

Performance characteristics for the breed crosses are reported in Table 1. Sire breed of the dam was a highly significant source of variation for initial and final weight and backfat, average milk yield, and actual and adjusted daily ME intake. Red Poll-sired cows had lower ($P < .05$) mean initial and final weights, and cows sired by either Chianina or Maine Anjou were the heaviest ($P < .05$). The sire breeds of dams reported in the present study were included in an analysis of growth characteristics reported by Jenkins et al. (1991), which reported mature weights estimated from nonlinear regressions and had rankings of sire breed of dam for predicted mature weights similar to the rank for initial and final weight in the present study. Angus/Hereford-sired cows had greater probe depths both at the start and at the end of the study than did the other groups. During the trial, probe depth in this breed cross increased. With the exception of the Chianina, probe depth of the cows of the remaining sire breeds tended to remain the same or to decrease slightly.

Means and SE for milk production are reported in Table 1. Angus/Hereford-sired cows and Chianina-sired cows produced similar amounts of milk and were exceeded by the other sire breed of dam groups ($P < .05$). The ranking for average milk yield was similar to the ranking for total lactation yield reported for these breed crosses by Jenkins et al. (1986).

The F_1 cows by Angus/Hereford sire breeds had the lowest ($P < .05$) adjusted daily ME intakes. Cows sired by Brown Swiss, Chianina, and Gelbvieh consumed the greatest ($P < .05$) quantity of ME. Ferrell and Jenkins (1984) indicated that daily ME intake required to maintain a weight equilibrium increased among breed crosses with greater mature size and milk production potentials. With the exception of the Maine Anjou, the differences among the breed crosses for weights of the cows and milk yield and adjusted daily ME requirements from this study support the previous conclusion. The ME consumption of Brown Swiss-sired cows exceeded ($P < .05$) that of the Angus/Hereford-sired dams, even though the final weight was the same. Red Poll-sired cows consumed more ME, even though these cows were smaller ($P < .05$) than Angus/Hereford-sired dams. The contribution of size to daily ME consumption was observed between Brown Swiss- and Red Poll-sired cows. The average milk yield was the same, but ME consumption of the larger Brown Swiss cows ($P < .05$) exceeded that of the Red Poll cows ($P < .05$). Though behavior charac-

TABLE 2. MEANS AND STANDARD ERRORS FOR PERFORMANCE CHARACTERISTICS OF SIMMENTAL-SIRED CALVES FROM CROSSBRED COWS

	Sire breed of cow[a]							
Trait	Angus/ Hereford	Brown Swiss	Chianina	Gelbvieh	Maine Anjou	Red Poll	SEM	Significance
Weight, kg								
Birth wt	39[b]	42[c]	45[d]	42[c]	45[d]	43[c]	.8	**
Initial	79[b]	91[c]	91[c]	92[c]	93[c]	89[c]	2	**
Final	231[b]	252[c]	245[c]	249[c]	254[c]	246[c]	4	**

[a]Mated to Angus and Hereford cows.

[b,c,d]Means within a row with different superscripts differ ($P < .05$).

$^{**}P < .01$.

teristics were not measured, the Maine Anjou F_1 cows were noticeably more docile than other breed groups, especially the Chianina F_1 cows, throughout the trial in both years. This could explain the divergence in ME consumption from the observed trend; the Chianina ME consumption was more comparable to that of the breed crosses with higher milk yields. Montano-Bermudez and Nielsen (1990) reported that cows with lower genetic potential for milk production but similar potentials for mature size consumed less food energy during a production cycle than cows with higher milk production potentials. McMorris and Wilton (1986) reported significant differences in ME consumption between Hereford and Simmental cows during the lactation period. These differences were related to level of milk production and size difference between the breeds. Bowden (1980) and Brown and Dinkel (1982) reported differences among breeds or breed cross groups for various measures of food energy consumption. Results from those studies suggested that differences in consumption were primarily attributable to body weight.

Birth weights and initial and final test weights for Simmental-sired progeny from the sire breed of dam groups are reported in Table 2. The effects of sire breed of dam and year were significant for the three traits. Heaviest birth weights ($P < .05$) were observed for progeny of cows from Chianina and Maine Anjou sire breeds. Progeny of F_1 dams from Angus/Hereford sires were the lightest ($P < .05$) at birth. Cundiff et al. (1986) reported a similar ranking among the breed crosses and similar weights at birth for these breed crosses. The means for weights at birth from that report were estimated from in excess of 400 birth records/sire breed of dam. At approximately 48 d of age, weights for the progeny of all the breed crosses were heavier ($P < .05$) than the weights of the Angus/Hereford-sired F_1 dams, as were the weights at the end of the study. Significant differences in final weight (average age approximately 186 d) were not observed among the other breed crosses. Results for weaning weight of progeny were comparable to those for corresponding F_1 cow breed groups through 7 yr of age (Cundiff et al., 1986), except that deviations from Angus/Hereford were 6 to 9 kg less for progeny of Gelbvieh, Brown Swiss, and Chianina cows under the test conditions of drylot and creep feed. The weights reported by Cundiff et al. (1986) were recorded from calves raised at pasture.

Means for cumulative food energy intakes for F_1 cows and progeny, weight gain of the progeny during the test period, and food energy conversion efficiency ratios are reported in Table 3. Differences in ME consumption of the progeny were not observed ($P > .05$). Differences due to direct genetic effects are not expected to be great among progeny groups differing only by 1/4 contribution of their maternal grandsire. There was a tendency for progeny of higher-milking Brown Swiss-, Gelbvieh-, and Maine Anjou-sired F_1 dams to consume less creep feed than progeny of Angus/Hereford-sired F_1 dams ($P < .15$). Green et al. (1991) reported that creep feed consumption by progeny of dams sampled from several breed crosses did not differ ($P > .05$). The results from Green et al. (1991) and the present study are in contrast to results reported previously (Bowden, 1980; Brown and Dinkel, 1982). Results presented by these researchers indicated that progeny from dam breed groups characterized as having lower milk yields consumed greater quantities of

TABLE 3. MEANS AND STANDARD ERRORS FOR COMPONENTS OF EFFICIENCY RATIO FOR CROSSBRED COWS

	Sire breed of cow[a]							
Trait	Angus/ Hereford	Brown Swiss	Chianina	Gelbvieh	Maine Anjou	Red Poll	SEM	Significance
Input cumulative ME intake, Mcal								
Progeny[e]	792	734	739	711	730	761	35	ns[g]
Cows[f]	3,444[b]	3,966[d]	3,923[d]	3,965[d]	3,793[c]	3,629[bc]	63	**
Output, kg[e]								
Weight gain	152[b]	161[c]	154[bc]	157[bc]	161[c]	156[bc]	3	**
Efficiency ratio, g/Mcal	35.8[b]	34.3[bc]	33.1[c]	33.7[c]	35.6[b]	35.7[b]	.56	*
Efficiency ratio relative to mean, ×100	103	98	95	97	102	103	—	—

[a]Mated to Angus and Hereford cows.

[b,c,d]Means within row with different superscripts differ ($P < .05$).

[e]Means for weight gain and ME consumed for the 138.5-d test.

[f]Mean adjusted ME consumed to maintain BW.

[g]ns = Nonsignificant.

*$P < .05$.

**$P < .01$.

creep feed. Among sire breed of dam groups, the rank and differences among the breed cross groups for total food energy consumption were the same as those reported for daily ME intakes.

A significant sire breed of dam effect on output (weight gain of the progeny during the test period) was detected. The weight gains of progeny from Brown Swiss- and Maine Anjou-sired F_1 cows were greater ($P < .05$) than the weight gains of the progeny from Angus/Hereford-sired F_1 cows. The weight gains of breed crosses with moderate potential for either size (Red Poll-sired F_1s) or milk yield (Chianina-sired F_1s) did not differ ($P > .05$) from other moderate and higher potential breed crosses. The weight gain of the progeny from the F_1 Gelbvieh-sired dams did not differ significantly from the weight gain of progeny from other breed cross groups.

Differences among the sire breed of dam groups were observed for the ratio of progeny weight gain to megacalories of ME consumed by the cow and the calf during the test period. Differences among the breed crosses for conversion efficiency seem to contrast breed crosses with genetic potential for moderate mature size with breed crosses with greater potential for mature size. Angus/Hereford- and Red Poll-sired dams' efficiency ratios were greater ($P < .05$) than the ratios for Chianina (large size) and Gelbvieh (large size and higher milk production) but did not differ ($P > .05$) from those for the Maine Anjou (large size) or the Brown Swiss (higher milk production). Results from a study of similar design reported by Green et al. (1991) did not indicate significant differences for breed of sire of dam effect for the same ratio. However, Green et al. (1991) did report a significant difference between breed crosses sired by *Bos indicus* and those sired by *Bos taurus* for efficiency of conversion of food energy to calf weight during the test interval.

Discussion

Conflicting results are in the literature with regard to the likelihood of differential conversions of food energy to a product among breeds or breed crosses of cattle. Holloway et al. (1975), Marshall et al. (1976), and Bowden (1980) concluded that among first-calf heifers of differing breed crosses the conversion of food energy to weaning weight of the calf was not affected by breed cross. Brown and Dinkel (1982) concluded that the conversion of food energy to weaning weight was similar among mature Angus, Charolais, and reciprocal cross cows through weaning. Klosterman and Parker (1976) reported nonsignificant differences in the feed/unit gain of weaned calves out of Hereford, Hereford × Charolais, and Charolais cows. Davis et al. (1983a,b) used results from several studies to investigate life cycle production efficiency of various breeds and breed crosses and the relationships between production efficiency and descriptors of cattle phenotype. Information from these life-cycle efficiency studies indicated that significant variation exists among breeds or breed crosses for the efficiency of production of weaning weight. Differences among breeds or breed cross groups were most apparent as the quantity of food energy available for production varied.

Evidence of variation among breed crosses for efficiency of conversion of food energy by the dam and her progeny to weight gain of the progeny is provided by the results of the current study. Alternative reasons for these differences should be considered. Of the two energy input components (cow and calf ME intakes), the means and variation were much greater for intakes of the dams than for those of the progeny. Therefore, variation in efficiency seems to be more dependent on ME consumption of the dam than on that of the progeny. Implicit in the study was the assumption that inherent variation existed among the breed crosses for quantity of food energy intake required to maintain weight stasis. It is believed that this variation can be attributed to differential energy requirements associated with differences in genetic potential, mature size, and milk production in cattle. Significant genetic variation among breeds for mature size has been reported (Smith et al., 1976; Brown et al., 1989). Jenkins et al. (1991) reported estimated mature weights for numerous breed crosses, including the breed crosses involved in the present study. Jenkins et al. (1986) reported variation among breed crosses for amount of milk produced at peak lactation and total lactation yield. In addition to the above, evidence indicating a positive relationship between genetic potential for milk production and food energy expenditure for maintainence of cows has been reported (Lemenager et al., 1980; Jenkins and Ferrell, 1983; Ferrell and Jenkins, 1984; Taylor et al., 1986; Montano-Bermudez et al., 1990).

The current evaluation was conducted at the ME consumption level required to maintain initial weight plus energy for lactation. If the assumption of a positive relationship between genetic production and energy requirement/unit metabolic body size is correct, F_1 crosses with greater milk production potential would require more ME to maintain BW over and above that associated with higher milk production. Inspection of information for the Red Poll- and Angus/Hereford-sired F_1s supports this assumption. The average 12-h milk production of the Red Poll-sired F_1s was approximately 20% greater than that of the Angus/Hereford. Jenkins et al. (1986) reported a difference in milk yield at time of peak lactation of approximately 18% between these two breed crosses. Despite the fact that Angus/Hereford F_1 cows were approximately 8% heavier than the Red Poll-sired F_1 cows (504 and 468 kg, respectively), the ME intake tended to be slightly higher for the higher-milking Red Poll (Table 3). The net result was that the smaller Red Poll F_1 and Angus/Hereford F_1 cows were similar in production efficiency. Weights on test for Gelbvieh-, Brown Swiss-, and Angus/Hereford-sired F_1 cows were similar. Gelbvieh- and Brown Swiss-sired cows had 12-h average milk yield 30 to 40% higher than the Angus/Hereford-sired F_1s. To maintain BW during the test period, the two higher-milking breed crosses required approximately 15% more ME. This increased ME consumption required to maintain weight combined with smaller (%) increased calf gain resulted in less desirable efficiency ratios relative to the Angus/Hereford F_1s for these two breed crosses. These results seem to substantiate the conclusion that variation in efficiency among cattle breeds differing in BW results from the positive relationship between the genetic potential for milk production and maintenance energy requirement. Behavioral characteristics that were observed but not quantified may have obscured the effect of this relationship on the efficiency estimates of the Chianina- and Maine Anjou-sired F_1s.

A second factor thought to be contributing to the observed differences in efficiencies is the choice of the breed used for sire of the progeny. Fitzhugh et al. (1975) indicated that the output for a beef production system could be enhanced by mating systems that exploited size differences between the paternal and maternal lines. This exploitation required that the maternal production characteristics be sufficient for expression of growth characteristics of the sire line. Progeny in the present study were sired by a third sire breed, Simmental. Because the dams were F_1s, the additive breed effect differences among the progeny would not be greater than a quarter (sire breed of the dam). Differences in milk yield of the dams was compensated for by availability of food energy from creep (breed mean correlation between milk production and creep feed consumption was −.61). The combination of food energy from creep and milk could have been sufficient for the expression of weight gain for crossbred groups that produce moderate amounts of milk, resulting in significant but marginal differences among the crossbred groups (Table 3). The present matings favored crossbred cow groups with smaller size with either moderate or high milk production potentials. Crossbred groups with greater genetic potential for mature weight would not have realized a similar benefit from additional growth potential from a large third breed of sire to produce the progeny.

Conclusions

Differences existed among F_1 breed groups of cows in weaning weights of progeny. Those F_1 cows that produced the heaviest calves required more ME to maintain BW during the lactation test period. Observed differences in output were totally or more than offset by differences in input when expressed as a ratio for efficiency of food energy conversion to weight gain of the progeny. The ratio for efficiency of conversion of food energy to weight gain of the progeny during the preweaning period was significantly affected by sire breed of the dam. Evidence was provided suggesting that these differences were attributable to variation among the breed cross groups for food energy required to sustain weight during the test period. These variations in maintenance energy requirements were related to differences in genetic potentials among the sire of the dam groups for either weight at maturity or peak daily lactation yield, or both. Crossbred groups with greater potential for milk yield varied in daily energy requirements based on the weights of the groups. Heavier weights and higher milk yield potential resulted in greater food energy consumption of the dam. The complementary effect of sire breed of the progeny on the efficiency ratios tended to favor crossbred cows with potential for lower food daily energy requirements (e.g., more moderate size). Future studies with the objective to evaluate differences in the efficiency of conversion of food energy intake to a measure of output should take into consideration the effect of complementarity on the trait of interest.

Implications

Exploitation of breed differences to enhance the efficiency of output production through use of mating systems requires consideration of the food energy requirement of the cow herd. Evidence indicates that moderate mature weights and levels of milk production potentially are biologically more efficient. When moderate-sized cows with moderate levels of milk production are mated to sire breeds with greater genetic potential for growth, the resulting complementary effect would be expected to be positive for efficiency of metabolizable energy use during the preweaning period for a production system.

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